Neural Computing: What Scale and Complexity is Needed?
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Neuromorphic computing at SNL leverages a legacy of research efforts.

**Neural Theory**
- NeuroXyce
- Computational Neuroscience
- Neural algorithms

**Applied Neural Systems**
- Biological Neuroscience
- Human Dimension
- Cyber data analysis

**Neural-enabling hardware**
- Memory technology
- Micro-sensors
- Non-von Neumann architectures

**Deployable National Security Applications**
- Cyber Defenses
- Embedded Pattern Recognition Systems
- Smart Sensor Technologies

**Enabling Advanced Scientific and Data-driven Computing**
- Neural-inspired communication paradigms
- Adaptive memory management
- Robust machine learning
HAANA is taking a broad approach to leverage neural algorithms in applications.
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**Guiding principles to our approach:**

1. **Bring rigor and formality to neural computing algorithms and hardware**
2. **Be deliberate in how we use neural inspiration**
3. **Be open minded about where impact may lie**
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Neuromorphic research often confuses neural *scope* with desired computational *abstraction*
Scope

Adult neurogenesis
Continuous formation of granule cell neurons throughout life
Scope

Dentate Gyrus
Millions of primarily GCs but many different varieties
Scope

Hippocampus
“Three layer” cortical like region responsible for memory and spatial processing
Scope

- Brain
- Regions
- Layers
- Neurons
- Proteins, DNA, and cellular structures
A good approach to look at is the scope that provides a useful function...
Identify functions that are both clear and have value

**Cognition**
- One shot learning, associative memory
- Pattern separation, conjunctive encoding
- Novel information encoding

**Brain**
- Hippocampus
- Dentate Gyrus

**Spiking dynamics**
- Neurogenesis
- Na+ Channels
Desired computational function should determine scope

Cognition

One shot learning, associative memory

Brain

Hippocampus

Pattern separation, conjunctive encoding

Dentate Gyrus

Novel information encoding

Neurogenesis

Spiking dynamics

Na+ Channels
Level of neural abstraction should be determined by functional need

- Pattern separation & conjunctive encoding
- Auto-association & Recursive Dynamics
- Temporal associations & Cortical-Hippocampal Comparisons

Dentate Gyrus → CA3 → CA1
Produce high level model and provide increased resolution as needed.
Systematic abstraction becomes necessary with high complexity

Computational Dentate Gyrus → Goal of proving larger model with clear function

Which components are necessary to produce desired pattern separation function?

- What scale?
- What types of plasticity?
- What resolution?
- What types of neurons?
Realistic simulations can guide abstraction for computing

- What neural scale?
- What cell types?
- What plasticity?
- Neurogenesis?
- Etc...

DG model with realistic neuron types and numbers, anatomy-guided connectivity, and detailed neurogenesis
Realistic simulations can guide abstraction for computing

Measure “compressibility” of activity

Measure magnitude of activity
Reduced scale simulations are qualitatively different than realistic scales.
Neurogenesis is critical for encoding and separation, but depends on scale

25,000 Granule Cells

300,000 Granule Cells

Improved pattern separation

More information encoded
Can use formal UQ / SA techniques to inform path to abstraction

- **Important**:  
  - Scale is critical  
  - Neurogenesis is necessary form of plasticity to encode novel information

- **Less important**:  
  - Interneuron diversity  
  - Specific neuron dynamics

* For these specific functions

**Carlson, in preparation**
Abstracted concepts can become computing-friendly

Formalize dentate gyrus / neurogenesis sparse coding algorithm

Simulate at high level of neural fidelity

Identify critical aspects of computation (expansive scale; sparse activation; neurogenesis)

Severa et al., submitted
Can we systematically use this approach?

**N2A model framework and software**
- compositionally construct dynamical neural models
- compiles simulation codes
- potential “front-end” to neural hardware

*Rothganger et al., Frontiers in Neural Circuits 2014*
Can we systematically use this approach?

Rothganger et al., Frontiers in Neural Circuits 2014
Thanks!